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EXCERPTS FROM THE ANNUAL REPORT OF THE CHIEF OF THE WEATHER BUREAU FOR THE YEAR ENDING JUNE 30, 1930

By C. F. MARVIN

THE UNPRECEDENTED DROUGHT OF 1930

Foremost in the minds of all during a summer like 1930 is the question, what causes such abnormal conditions? No conclusive and comprehensive answer can be given. Moreover, the answer will need to be varied and adapted more or less to particular cases. Directing our answer particularly to the extensive drought of 1930, all we can say is that these unusual conditions are best explained as a prolonged stagnation of the air over nearly the whole continental extent of the United States. In ordinary years this great blanket of atmosphere overlying the continent is in more or less active circulation. Cool air from the polar regions moves southward from time to time. This feature of circulation has been especially absent this summer. Warm air from the tropical latitudes moves northward at intervals. Air from the oceans and Gulf moves inland, and there is a more or less active and continuous interchange of these different air masses, causing the agreeable and favorable conditions that prevail in ordinary years. This circulation and interchange has been conspicuously absent for a long time during the present great drought.

During this stagnation the occasional showers and thunderstorms here and there over the drought-stricken region served only to dry out the overlying air masses. Only a part, at best, of this water is evaporated back into the free air, and with little or no moisture borne in by winds from the oceans, each successive inland shower, coupled with the stagnation and absence of general rain-causing processes, tends to further deplete the moisture supply and intensify the drought condition. It may be pointed out, also, that over most of the United States the summer heat is normally at its maximum about the last week of July. Therefore, summertime stagnation and lack of active circulation within the continental air blanket causes the absence of precipitation and permits the culmination of excessive temperatures, but the experts are unable to assign a specific cause for the prolonged stagnation.

CYCLES AND SEASONAL WEATHER FORECASTS

The occurrence of any notable weather event, such as the drought of the summer of 1930, is always made the occasion for discussion of the possibility of predicting such happenings sufficiently far in advance to permit of steps being taken, if indeed any such are possible, to lessen the economic loss which is bound to result so long as they arrive unheralded.

Another even more futile imagination is that these untoward happenings can be caused or suppressed by man himself. For example, many letters are received urging that by the use of explosives and aerial bombardment we can cause plentiful rain. Curiously enough, another group of writers urge us to employ aerial explosives and bombardment to destroy hurricanes, tornadoes, etc. Here we have the absurd representation that by the use of exactly the same means we can supply rainfall to drought-stricken regions or we can suppress tornadoes, hurricanes, etc., which are frequently accompanied by even torrential rainfalls.

With reference to these and the possibility of future forecasting, the Weather Bureau continues to hold an entirely open mind and to seek for promising lines of attack on the problem of such forecasts, but we can not be led away from a sane and rational conservatism in these matters, either by the occurrence of great natural disasters or the confident assertions of advocates of this, that, or the other fanciful idea. In so far as a sound physical basis for seasonal forecasts is involved, the subject can be said to be still in the speculative stage. Some practical advances have been made by means of correlations, but the sum total of results attained by this method is relatively small.

The complexity of the problem is well illustrated by the weather extremes of the past year in different agricultural areas. While a great part of the United States was suffering for want of rain, western Europe was experiencing an extraordinarily wet harvest season, and in the great corn-growing region of Argentina the weather was so continuously wet as to delay the conditioning of corn for shipment overseas. It will be readily understood that until the different kinds of weather which occur simultaneously throughout the world have been satisfactorily correlated among themselves, forecasts therefor from a single factor, such as periodicity in sunspots or variations in solar radiation, can have no hope of success.

One line of attack on the problem of seasonal weather forecasts that is thought by meteorologists to offer some promise of success is that afforded by changes in the temperature of the surface waters of the oceans. It is well known that the oceans exert a pronounced influence on the climate of adjacent land areas. The character, amount, and extent of the influence depend on various circumstances, as latitude, direction of the prevailing winds, topography, and distance from the coast. Inadequacy of observations and other difficulties have hitherto operated to prevent any considerable investiga-

tions in this field by the Weather Bureau, although some preliminary work has been done in recent years. However, as a result of the development of commerce with Latin America and the opening of the Panama Canal observations from ships have been increasing from the strategic water areas embracing portions of the Atlantic equatorial currents and the Gulf Stream.

Much has been said by many people that weather phenomena recur in cycles. Naturally this whole subject is a very complicated one, and we all recognize the ups and downs, and the frequent extremes of heat and cold, wet and dry weather phenomena. A critical study of these phenomena has failed to disclose any such orderly system of recurrences as the word "cycle" connotes in the minds of most people. Forecasts on any such basis as this will fail quite as many times as they might succeed, and even at the best the intervals between recurrences are subject to such wide changes in length of interval, and the magnitude of the extremes, although sometimes large, are frequently entirely insignificant, so that the reality of cycles is very problematical, and forecasting by means of them is as yet unsuccessful.

The subject of correlations and periodicities of weather phenomena are under continuous investigation by one or more of the experts of the bureau, in the hope of discovering useful information.

WEATHER SERVICE FOR AIRWAYS

In previous annual reports, particularly those issued in 1927, 1928, and 1929, the bureau's service for flying activities was discussed at some length, principally from the point of view of organization and the legislation authorizing it. It seems proper at this time to indicate the general character of this service, as now organized, and to point out needs for expansion as the network of airways is still further extended.

As is well known, the Weather Bureau is charged with the duty of furnishing service for all interests—agriculture, commerce, and navigation, which last now includes the air as well as the sea. In doing this the bureau has organized a network of some 210 first-order stations, well distributed over the entire country. These stations regularly exchange reports twice daily and also keep continuous records of weather conditions for statistical and research purposes. The twice-daily reports are used in issuing summarized statements and forecasts, which are given wide dissemination by telegraph, telephone, radio, and the press. This may be called the bureau's general or primary service.

In addition, several more detailed and intensive services have been organized to meet special needs, including the protection of fruit and other crops from frost, warnings of conditions favorable for floods, forest fires, hurricanes, and other violent storms. For these services numerous second-order stations—several hundred of them—have been established at points from which experience shows that the information is needed. The reports are made by noncommissioned personnel, in accordance with prearranged schedules, or on call.

The most recently organized of these intensive services is that for flying activities on commercial airways. The bureau's authority for this service is defined in section 5 (e) of the air commerce act of 1926. In organizing the service, close cooperation is maintained with the Department of Commerce, which is charged with providing communication, lighting, and landing facilities for the airways. As a rule, detailed surveys of proposed airways are made jointly by representatives of both depart-

ments. In the course of these surveys a study is made of past records in order to determine the general character of the weather conditions that are likely to be encountered. Pilots and officials of the air-transport companies and others who are familiar with the section are consulted with a view to determining what the needs are and how to meet them. Finally, a program of service is formulated and organized. Naturally, it is necessary to keep this program within the limit of funds appropriated for the purpose, and also to distribute those funds equitably and impartially to all sections of the airways system.

The basic features of the service are timely reports of current conditions and short-period forecasts. In other words, the aim is to give the pilot the weather of the "now" and the "soon to be." To do this, special observing stations are established along and near the airways. The distance between these stations varies from 5 to 10 to 100 miles, depending on the topographic and meteorological characteristics of the section. The time interval between reports also varies, this depending largely on the volume of traffic. Where flying is more or less continuous both day and night, reports are received from all observing stations on the airways once each hour, and in some cases intermediate half-hourly reports are received from the more important terminal stations. On airways having as yet but little traffic—one regular daily flight each way, for example—the reports are timed to fit the schedules. This latter type of service as a rule characterizes only the earlier stages of an airway's history. As flying increases and off-schedule flights become common, experience shows that the needs for service can be met adequately only by frequent and regular reports.

Attention is invited to the accompanying chart, which shows the airways for which service is now furnished. At about 50 of the more important terminal airports on these airways the bureau has established continuous 24-hour service, with full instrumental equipment and personnel of 4 to 7 technically trained men. At some 250 intermediate stations the observations are made by properly instructed, though not technically trained, personnel, who report the conditions as observed by eye or with comparatively simple instrumental equipment. Reports from these special stations are transmitted to the bureau's more important centers on the airways.

Naturally the prompt collection of these reports (and unless they are prompt, all the effort is wasted) requires a highly efficient communication system whose organization is a function of the airways division of the Department of Commerce. It was early found that for this particular purpose, dependence can not be placed on the ordinary commercial facilities. During the time of peak loads—that is, in the middle of the day—absolute promptness could not be guaranteed. All types of business are entitled to equal service. It was evident, therefore, that a system of communications under absolute control is necessary. This has been accomplished on some of the main airways through the installation of a printing telegraph, or teletype, circuit. The circuits consist of leased telephone lines, 500 to 800 miles in length, between terminal airports, with drops at the intermediate weather-reporting stations, each one of which has an automatic typewriter, or teletype machine. The messages are typed on these machines in sequence, the various stations following one another in rapid succession, and each message is received on tape by all other stations in the circuit. This

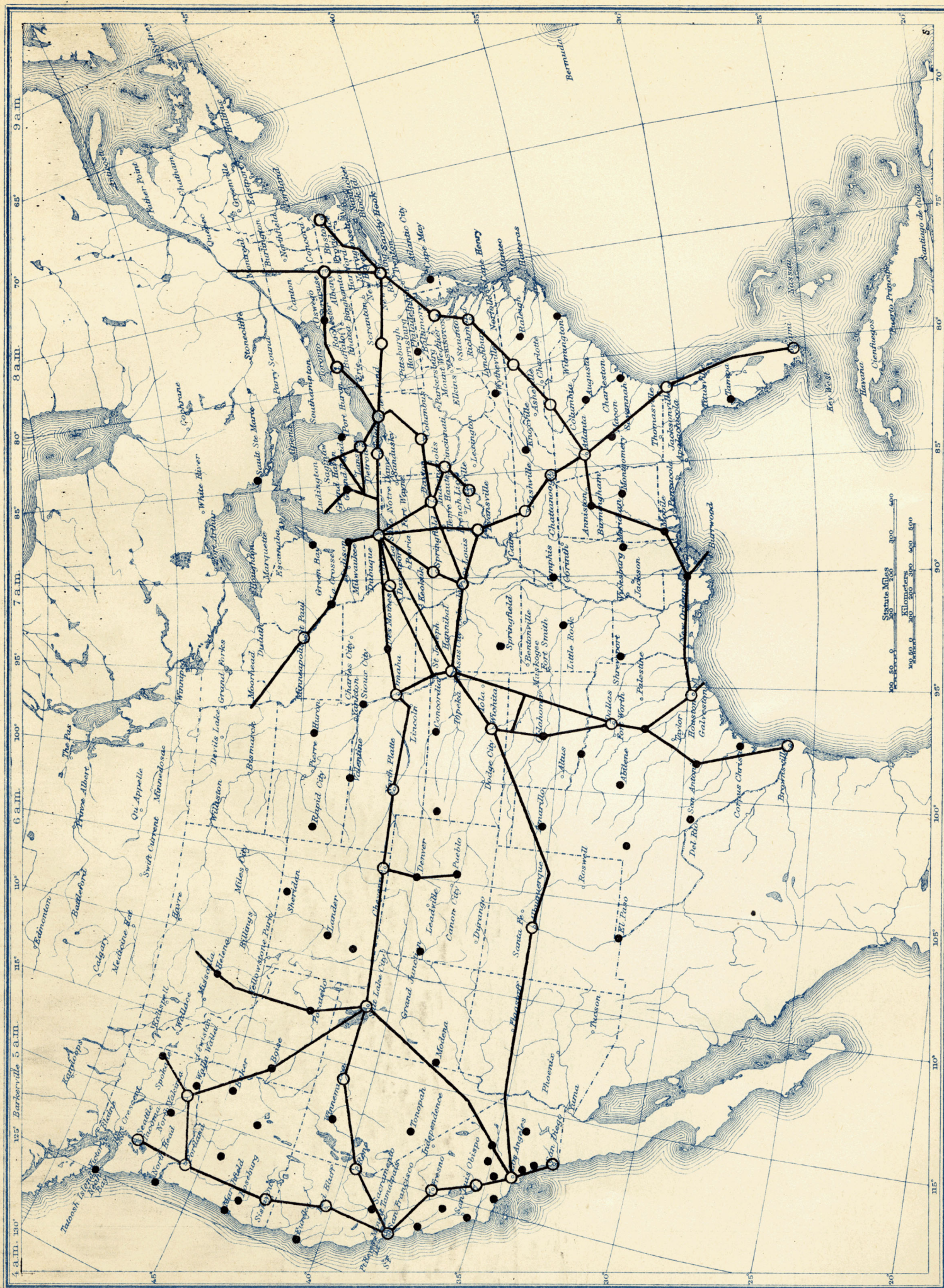


Chart showing commercial airways for which intensive weather service has been organized. Open circles are Weather Bureau airport stations, with continuous 24-hour service. Dots are additional stations off the airways that furnish three-hourly reports to designated centers.

system of communications is prompt and is rapidly increasing in efficiency and reliability. The Department of Commerce plans to extend it eventually to all interstate trade air routes.

All reports, whether sent by teletype, telephone, telegraph, or radio, include information concerning the following elements: General condition of sky and weather; ceiling; visibility; surface wind direction and velocity; temperature; barometric pressure; and miscellaneous conditions, such as thunderstorms, squalls, and state of landing field as affected by rain, snow, etc.

In many cases dew point is also reported, and some of the airport stations (about 45 at present) give detailed data of wind direction and velocity at various heights.

For the general condition of sky and weather no instruments are required, but certain definite terms have become standard for expressing it, such as "clear," "broken clouds," "overcast," "fog," "heavy rain," "sleet," etc. This first word in the report tells the pilot at once whether conditions are satisfactory, impossible, or simply uncertain and therefore subject to further study.

The next two items, ceiling and visibility, usually answer this question of uncertainty. For observations of ceiling at night when clouds are present the so-called "ceiling light" is in general use. A beam of light is shot upward, in some cases vertically, in others at a 45° angle, and in still others at some intermediate angle. The use of this instrument has not as yet wholly passed the experimental stage, but the consensus of opinion is that a vertically projected beam gives the best results. There is still some uncertainty also as to the most satisfactory intensity. At present 250-watt bulbs are in general use, although a higher intensity is favored by some, especially for stations in mountainous country, where high ceilings are essential for safety. In all cases the beam makes a spot of light where it strikes a cloud. This spot is more or less definite and well marked, depending on the density of the cloud mass. The height of the spot, and therefore of the ceiling, is determined by means of an alidade, or clinometer. The angular reading of this instrument, together with the known distance of the light source from the point of observation, provides the necessary data. In many cases the alidade is graduated in heights instead of degrees and thus eliminates the need of computation or the use of tables or graphs.

For observations of ceiling in the daytime, so-called "ceiling balloons" are used. These are about the size of ordinary toy balloons, although of a somewhat better quality. They are filled with hydrogen until just capable of sustaining a 40-gram weight. When released, they rise at a known and fairly constant rate. It is then only necessary to note accurately the exact time of their disappearance in the cloud. As in the case of ceiling lights, when the cloud mass is of a light and tenuous nature there is some slight uncertainty as to the exact moment of disappearance, and it is general practice to report the height at which the balloon begins to be indistinct. Ceilings are usually given only to the nearest hundred feet. Greater precision is not warranted in view of the fact that the cloud base itself varies as much or more within relatively short distances.

Observations of visibility are noninstrumental. It is customary to give the greatest distance at which conspicuous objects can be clearly seen. Whenever practicable, lights are used at night. This method is approximate only, but fortunately it is most nearly accurate at times when the information is of most importance—that is,

when visibility is low. It should be stated that observations of visibility show conditions in the horizontal, not in the vertical. No attempt is made to measure vertical visibility except when clouds are low, in which case it is defined by the height of the ceiling.

These two elements—ceiling and visibility—have been dwelt on at some length for the reason that all pilots ask first for information regarding them. Many ask for nothing else if these are favorable. Whereas they were never thought of in meteorology before the days of flying, now they are among the most important working elements of the meteorologist whose duty it is to tell pilots what the weather is or is going to be.

Wind direction and velocity at the surface, temperature, dew point, and barometric pressure are all so well known, as also the instruments used in observing them, that only a passing reference is necessary. Information concerning surface wind is useful principally in connection with taking off and landing. Temperature and dew point together determine the likelihood of fog and of ice formation on the planes. Reports of pressure enable the pilots to correct their altimeters, in addition to furnishing the meteorologist with basic data for synoptic charts or weather maps.

Miscellaneous phenomena are observed directly without instruments. They include thunderstorms, line squalls, exceptionally heavy rain or snow, ice formation as reported by incoming pilots, and any other conditions a knowledge of which is useful and at times vital in determining whether or not flights should be made. Special attention is always given to this part of the reports.

For measurements of upper wind direction and velocity, so-called "pilot balloons" are in general use at airports. These balloons are about 6 inches in diameter and are made of pure rubber. Different colors are employed to give the best possible visibility against varying backgrounds of sky and cloud. The balloons, when filled with hydrogen, are about 28 to 30 inches in diameter and ascend at a nearly uniform rate of 600 feet a minute. Their ascent is watched with a theodolite, and angular readings are made each minute. By means of slide rule, portable telephone, and plotting board, computations are made while the observation is in progress, with the result that the wind conditions at various levels are known in detail within two or three minutes after the balloon disappears. For observations at night a small lantern is suspended a few feet below the balloon. Reports containing these data are received as a rule at the Weather Bureau's airport stations, where they are made available in various ways. In almost all cases the reports are posted on a bulletin board. If conditions are generally good, the pilots are usually satisfied with a reading of the bulletin; but, if conditions are uncertain in spots, individual copies are sometimes made for the pilots to take along on their flights.

Along with this organization by the Weather Bureau, the Department of Commerce has established a network of radio stations which broadcast the reports for certain airways once each hour. There are now about 40 such broadcasting stations. Some of the air transport companies have equipped their planes with receiving sets and others are doing so as rapidly as practicable. Thus, in addition to the information given at the airport stations of the bureau, the pilots receive supplementary reports while making their flights.

The broadcasts include not only reports of current conditions but also of expected changes for the next few hours. Short-range forecasts have already proved to be

a great aid, and it seems certain that, with the increased accuracy that is bound to come, they will ultimately constitute the most valuable feature of the weather service. There is some question as to most suitable period of time to include in the forecasts. Naturally the shorter the period, the more precise the forecasts; but, on the other hand, their value is limited unless they cover at least a reasonable period. As a basis for compromise, the maximum length of the great majority of flights has been chosen—that is, three to four hours.

As earlier stated, the basic material for all forecasting is the country-wide, twice-daily collection of reports which are used in constructing the well-known weather maps. The forecasts for 12 to 24 hours, based on these reports, are quite dependable but are necessarily given in general terms. What is needed is their amplification and localization. For this purpose supplementary reports from relatively small areas are required, small at any rate as compared with the country-wide, twice-daily system.

As an experiment, the period of three hours has been selected, the observations being made at 2, 5, 8, and 11 a. m. and p. m., seventy-fifth meridian time. About 110 stations are at present in this system. They transmit their reports to airways-forecast centers at Atlanta, Ga.; Cleveland, Ohio; Dallas, Tex.; Fort Crook (near Omaha), Nebr.; Oakland, Calif.; Portland, Oreg.; and Salt Lake City, Utah. The data are entered in detail on base maps, and lines of equal pressure are drawn. The maps for 8 a. m. and p. m., seventy-fifth meridian time, being based on the bureau's primary system of reports, are, of course, much more complete than are the six others. The latter are used as auxiliary to the former and serve to show the changes taking place in the areas for which the short-range forecasts are issued.

Although designed primarily for flying activities over established airways, the 3-hour system of reports and forecasts in large part also solves the problem of so-called off-airways flights. Before the organization of this system there was no provision for obtaining special reports from places not on regular routes except by special call and at the expense of the pilots desiring them. Now, however, information is fairly complete for large areas,

and anyone desiring reports for cross-country flights in those areas has only to listen in at the proper times, since these summaries are regularly broadcast, as well as the hourly reports of conditions along the established airways themselves.

Thus far the need and value of short-range forecasts have been stressed. They are relatively precise and cover approximately the duration of nearly all flights. But they will never do away with the necessity of the longer-period forecasts, to which, rather, are they supplementary. The 12 to 24 hour forecasts will become increasingly important. While the individual pilot is interested in the weather for a few hours, the operations manager of an air-transport line needs to make his plans as far in advance as possible. Particularly is this true if passenger service is included.

Thus, the three main features of weather service for aeronautics are each essential to the proper functioning of the others: (1) The frequent, individual reports tell of the weather now; (2) the short-range forecasts cover the individual flights or announce the weather that is soon to be; and (3) the basic general forecasts indicate the likelihood of successful flying to-morrow. Considered in reverse order, the general forecasts form the groundwork of the entire service; they are supplemented by the more intensive shorter-period forecasts; and both of these are still further supplemented by timely reports of current conditions, which check the forecasts previously made and provide data for slight modification in them, if necessary.

Again referring to the chart, the system of airways there shown is only a beginning. Already surveys are being made by the Department of Commerce for many additional lines, and eventually the entire country will be covered. As rapidly as these airways are established the Weather Bureau, to the extent that additional appropriations permit, will organize service for them, along the lines of the present service, with such modifications in details as experience may show to be desirable. Fortunately, the cost of these extensions will be considerably less per airway mile than that of the service thus far organized, since much of the latter will give information that will meet in part the needs of the new lines.

THE GREAT DROUGHT OF 1930 IN THE UNITED STATES—SUPPLEMENTAL NOTES

The previous paper on this subject (this REVIEW, September, 1930) was more or less incomplete owing to the uncertainty as to the end of the drought and the difficulty of quickly getting information from the field as to the progress of the drought in all sections. Several odds and ends have come to hand since the first account was printed. These will now be given:

THE DROUGHT EXTENDS TO THE PANAMA CANAL ZONE

Mr. R. Z. Kirkpatrick, chief of surveys, Canal Zone, supplies us with the data given in the table below showing conclusively that drought was felt almost to the Equator. The shortage of water yield was at a maximum in February and reached a second maximum in August.

TABLE 1.—Departure from the normal water yield, Chagres River and Lake Gatun, Panama Canal Zone, January–September, 1930

Month	Chagres River		Net yield Gatun Lake watershed	
	Above	Below	Above	Below
	Per cent	Per cent	Per cent	Per cent
January.....		44		39
February.....		45		48
March.....		34		47
April.....		3	1	
May.....		1	1	
June.....		20		38
July.....		18		26
August.....		40		39
September.....		15		26

—A. J. Henry.